Efforts to Develop High-Temperature Electronics

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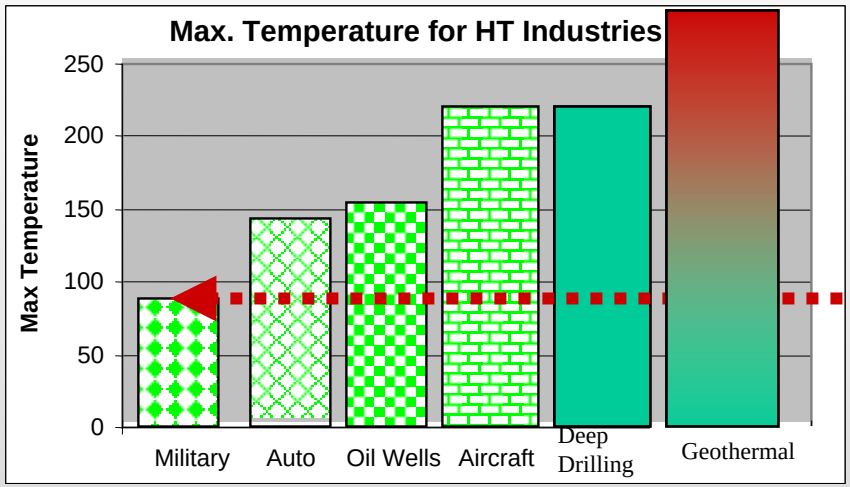
Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy under contract DE-AC04-94AL85000.

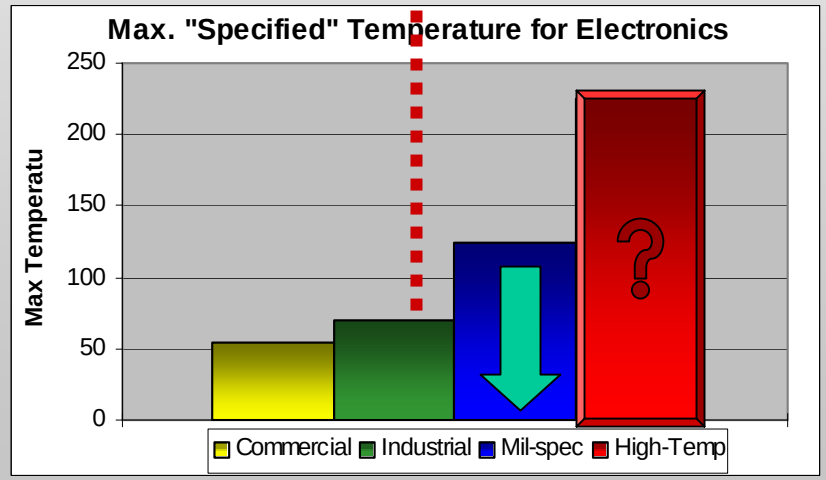
Sandia National Laboratories

HT Wellbore Applications Are Not Alone



The need for high-temperature electronics above the military specification is growing while commercial components are becoming increasingly temperature intolerant.

To meet that need new HT components are being developed commercially between 150-225 ºC! However, each company is setting their own requirements.



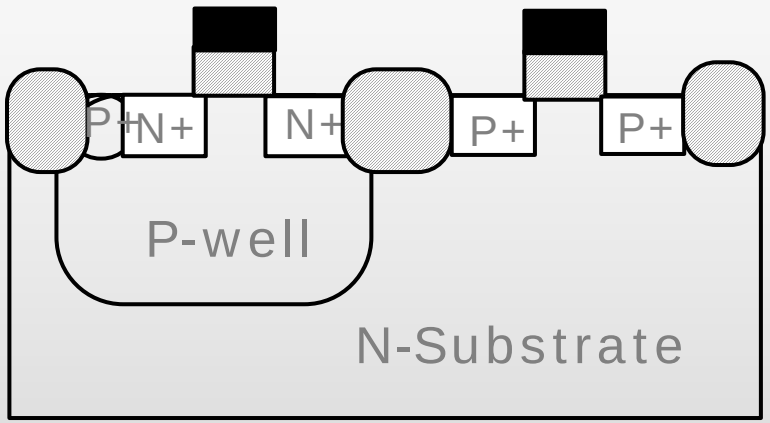
Why HT Components

- Industrial grade electronics are designed for 85°C and a 1-2 year operating life at temperature
  - These components are being screened by the service companies
  - MWD tool designers shoot for 100 hrs@ 200C of operational life at temperature
- Electronic industry rolls over ~ every 6 years
  - HT capabilities are lost when manufacturers only support 85°C
  - Service companies do life of program buys
- If a complete HT solution exists engineers will use it, if not then nothing in the industry will change

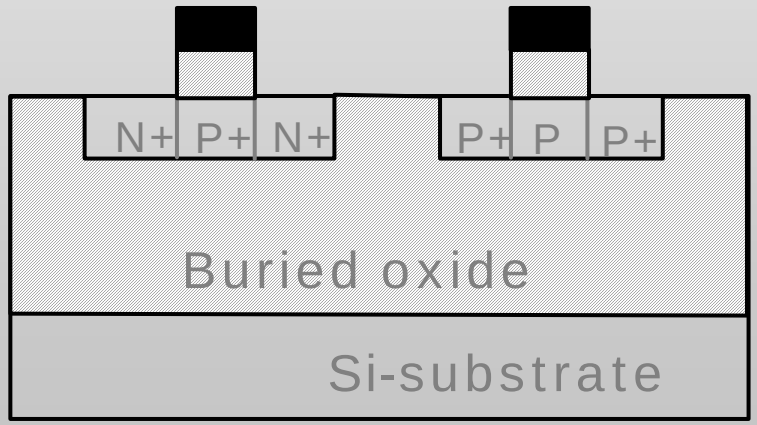
Demonstrating a Complete Solution

- Sandia built a 250ºC logging tool
  - We built a complete working 250 ºC logging tool by working with Silicon-On-Insulator (SOI) technology!
  - We are using this tool to further evaluate new High-Temperature Long Life (HT2L) components
  - We are openly publishing our design
  - Working to create new industry standards for the component industry
  - Helping consumers to understand the value of HT2L designs

SOI vs Bulk Silicon



A: Cross-section of bulk CMOS inverter



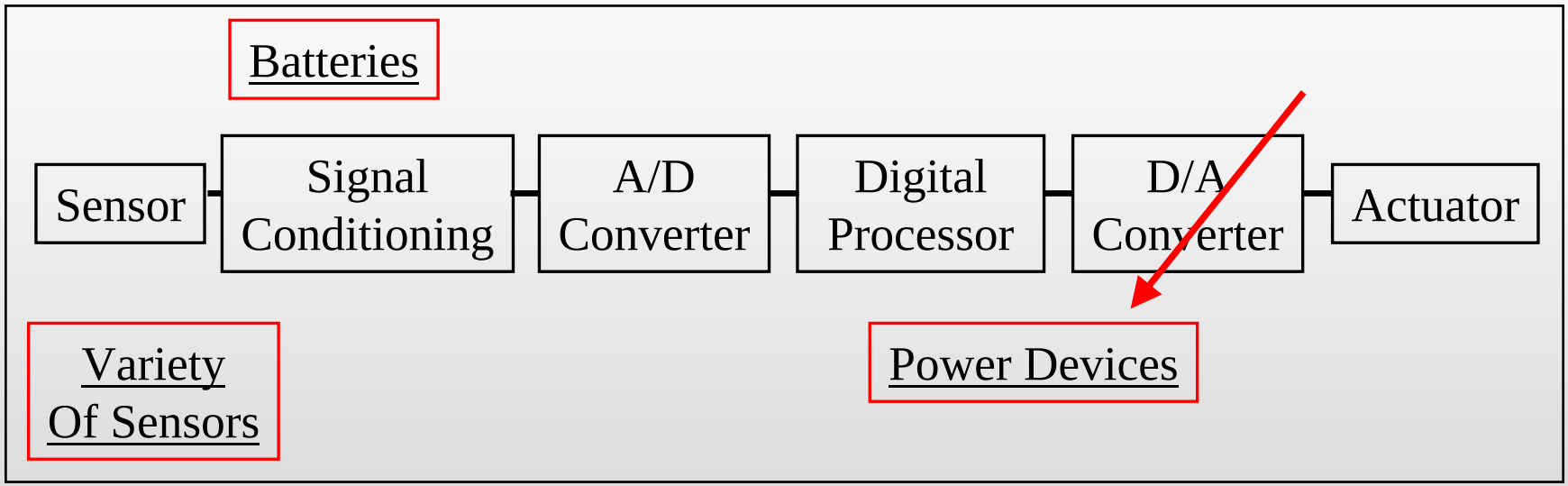
B: Cross-section of a SOI CMOS inverter

- SOI electronics build transistors on a non-conducting layer to greatly reduce thermal generated error current (~100X)
- This is simply the best method for reliable integrated circuits

Silicon-On-Insulator Technology

- Much of the silicon technology already exists!
  - SOI (silicon-on-insulator) has been known for ~ 20 years
  - In 1993 Honeywell started product development of SOI to support commercial aircraft electronic engine controls
  - First of 13 components became available in 1995
    - Electronic components qualified to 225 ºC (437 ºF)
    - Components go through a 250 ºC (482 ºF) burn-in
  - Directed toward commercial aircraft engines controls
    - Aircraft engines require 44,000 hrs (5 yrs) of operation at 200 ºC (392 ºF) without failure!

First Application: Turbine Engine Controllers



Swenson, Gregg and Ohme Bruce, "HTMOS: Affordable High Temperature Product Line", HiTEC 1996, pg P89-P94.

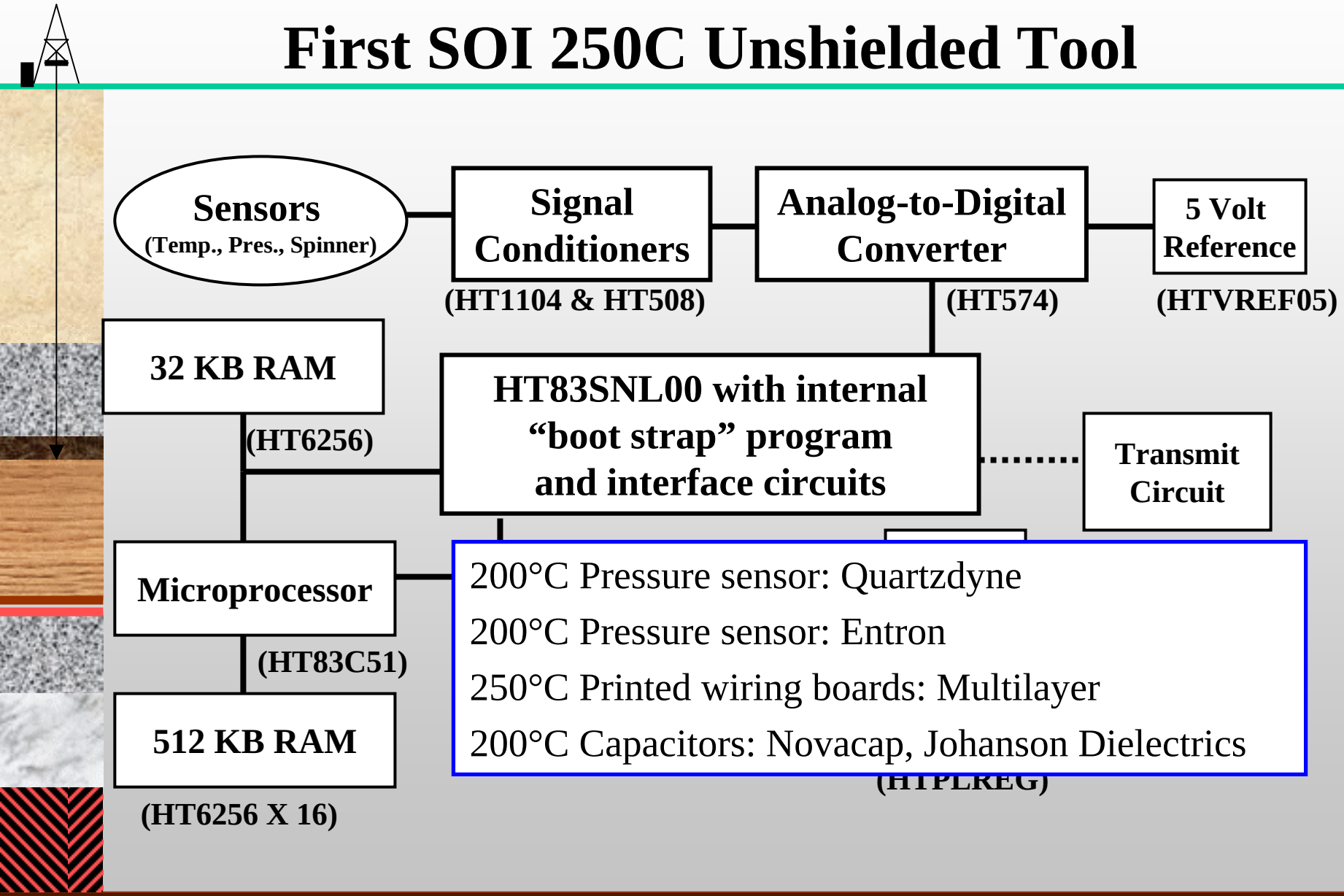
In general, aircraft engine controller contains most of the electronics needed for building a logging tool.

However, MWD tools require batteries and power devices

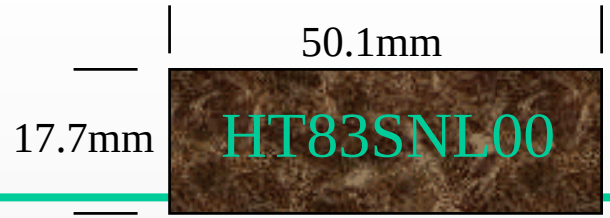
The upstream industry uses a large variety of sensors

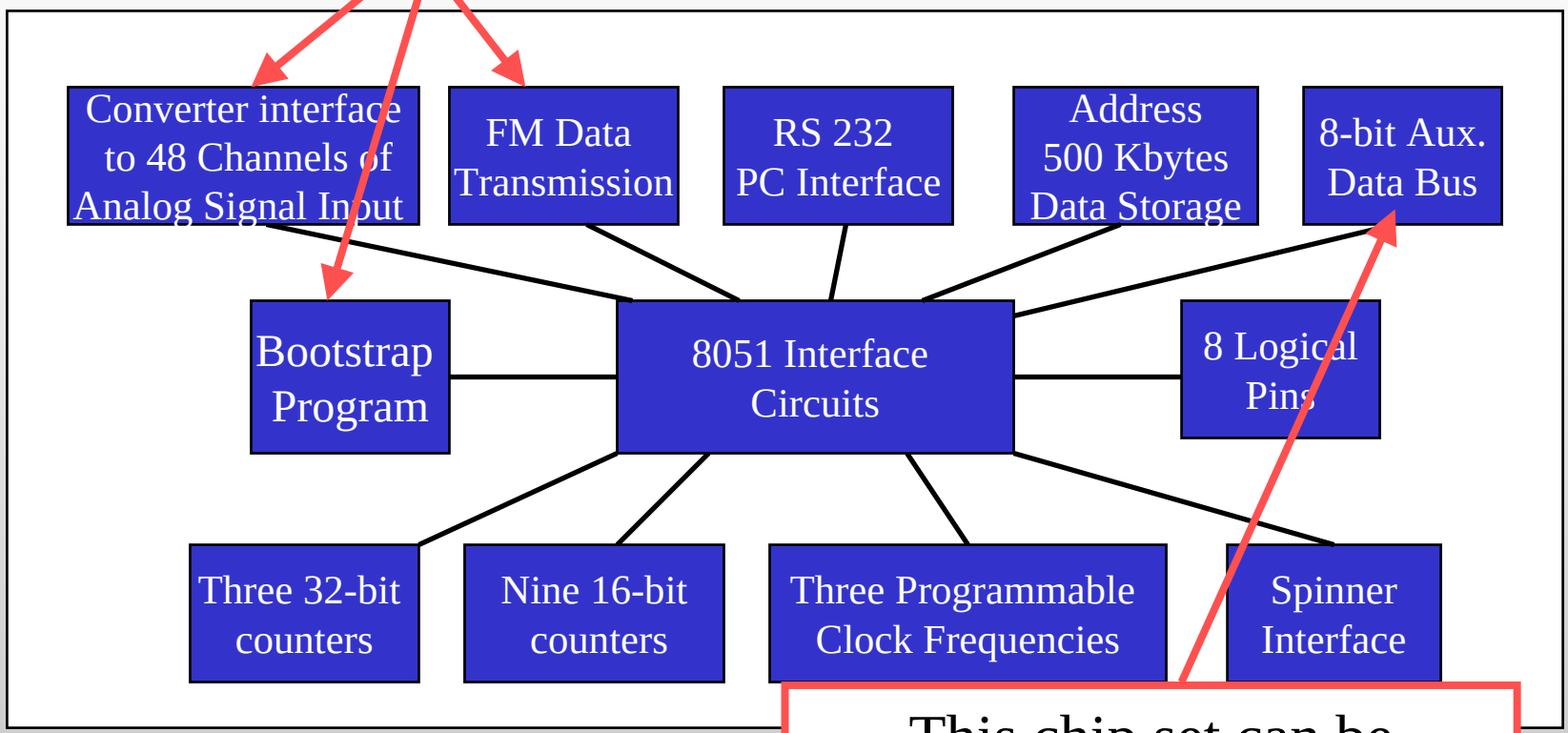
In general, tools are scientific in nature using 16 bit data

First SOI 250C Unshielded Tool



Chip set will power up and start logging for easy operation



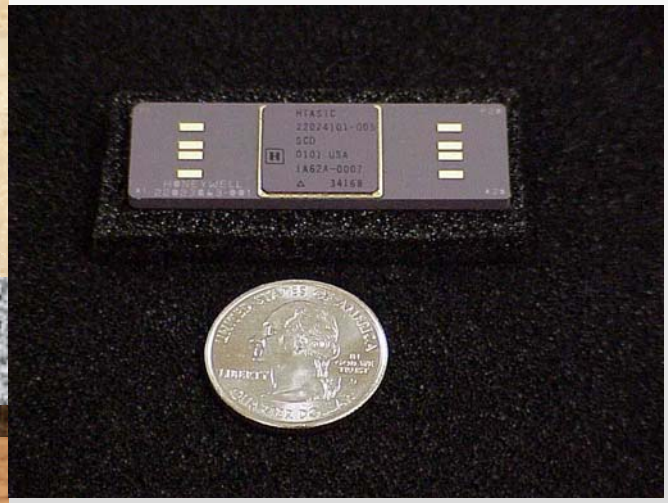


The package will have a 0.7in (17.7 board size down and have a 0 to 30

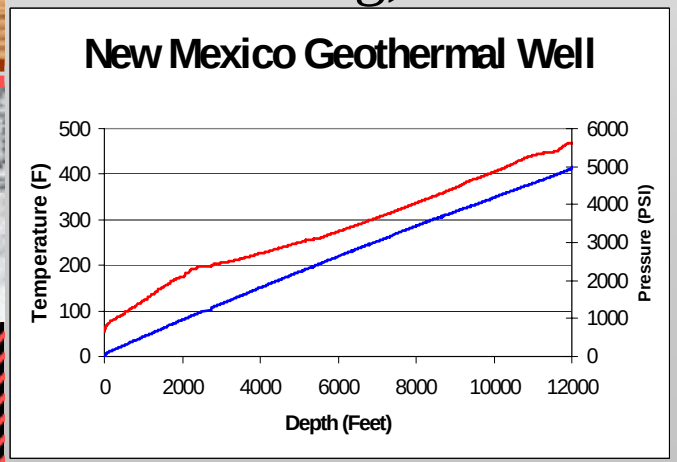
This chip set can be master/slave configured for doubling the number of data channels!

New Chip Enables Tool Development

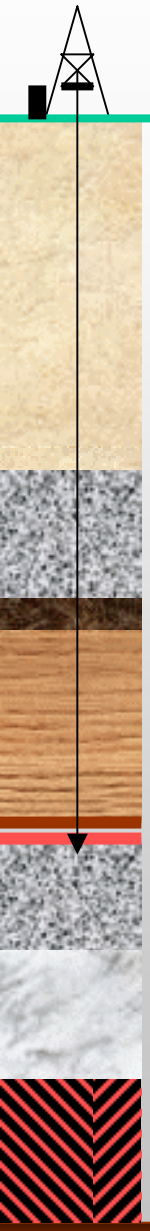
The ASIC



Bearfoot Log, 240°C



- The HT83SNL00 chip is the foundation of the USGS downhole monitor.
- Nov 2001, completed a downhole test inside a 240°C well for some 40 hrs (two other wells at 200°C, 210°C also were logged).
- After well log, the tool was placed within an oven at 225°C for 1200 hrs and then 500 additional hrs at 250°C!!!
- The downhole monitor uses HT SOI electronics and a Quartzdyne P/T sensor



Laboratory Testing of Honeywell SOI

- Reliable Operation Demonstrated For 225ºC
  - Over 2.2M Devices Hours at 225ºC with 300K hours MTBF
  - Established wear out times of greater than 5 Years at 225ºC
  - TRW has presented similar data independent of Honeywell
  - Apparent MTBF of 10 years at temperatures < 175 ºC
  - Potential for 15-20 year MTBF at temperatures < 125 ºC
- Conventional “Bulk” silicon electronics can not compete with temperature and life performance
  - Industrial grade electronics have no life requirement
  - Plastic packaging of electronics out-gasses flame retardant at 175C causing random component failures

Quartzdyne P/T Sensor Life Testing

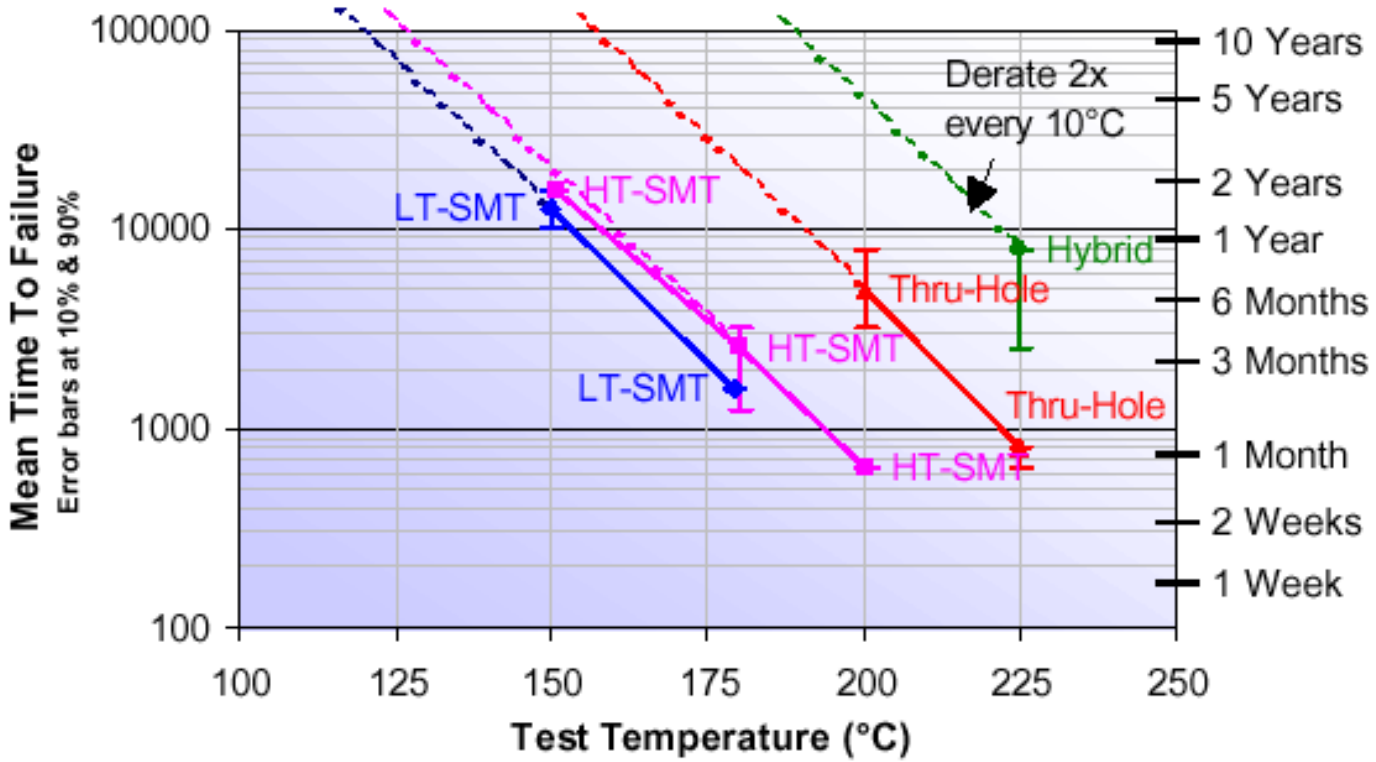


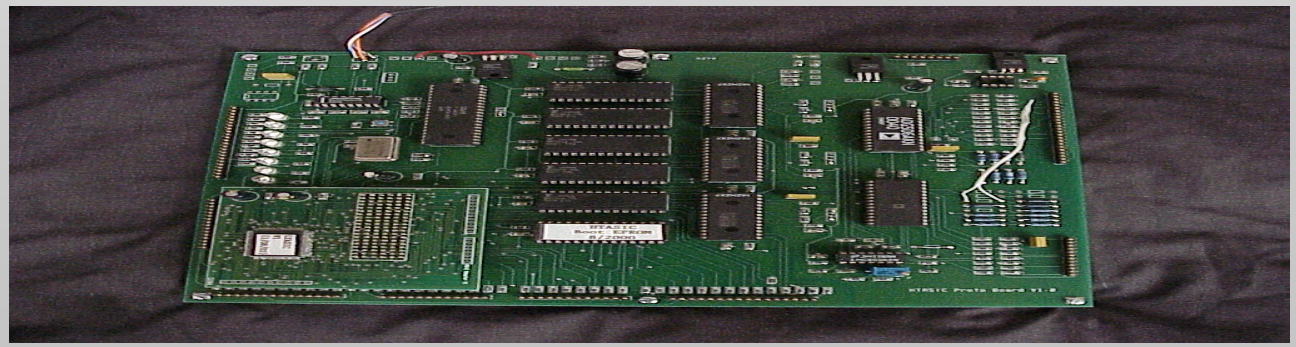
Figure 3. Life/Cycle Test De-rating

Commercialize to Jump Start Industry

- Sandia is working with companies to develop new high-temperature, long life products from PTS tools to intelligent well completion systems
- By helping a few companies develop new high-temperature long life tools, we hope to jump start component industry while educating consumers to expect more from the service providers.

Education to Aid Commercialization

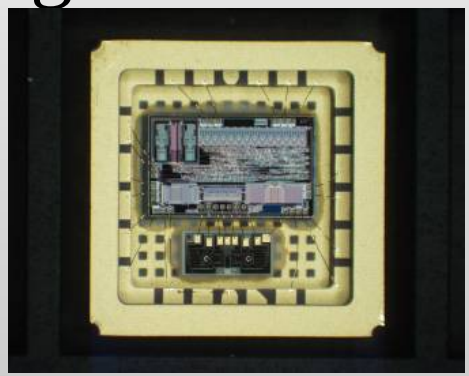
- Technical learning aids are extremely important to small service companies
  - Giving the industry a low temperature evaluation board to simulate Sandia SOI designs
    - » Documentation is good but a prototype is worth a 1000 man-hours.
  - Jump start selected service companies with a high-temperature components to get them fully started.



Ongoing Initiatives In Support Of HT Tools

- Composite battery starting next year (NETL)
  - 175-250°C Batteries: Eagle-Picher Industries
  - 25-300°C Keep-A-Live Batteries: General Atomics
- +200C HT Polymer capacitors: Sigma Technologies
- Micro-Machine / SOI

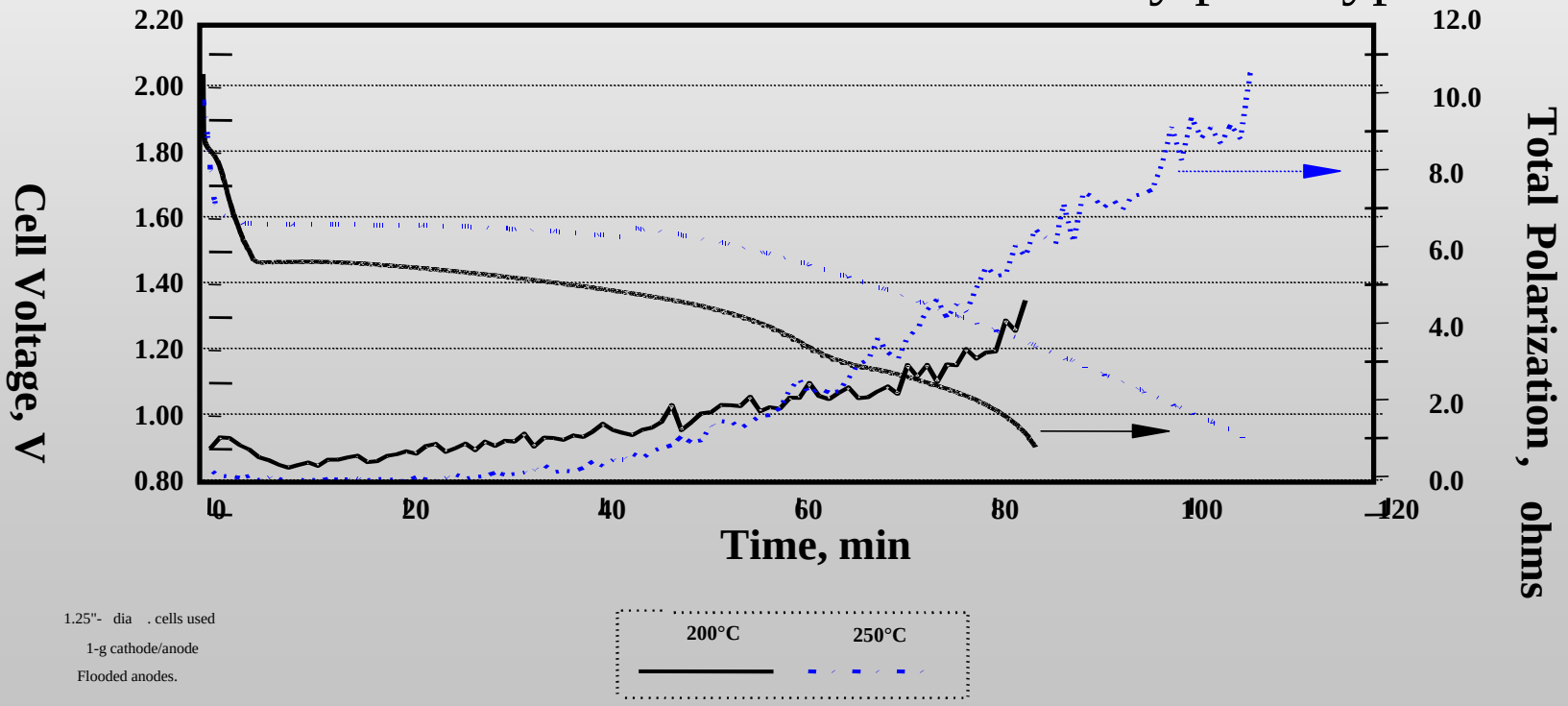
inclination sensor: Silicon Designs



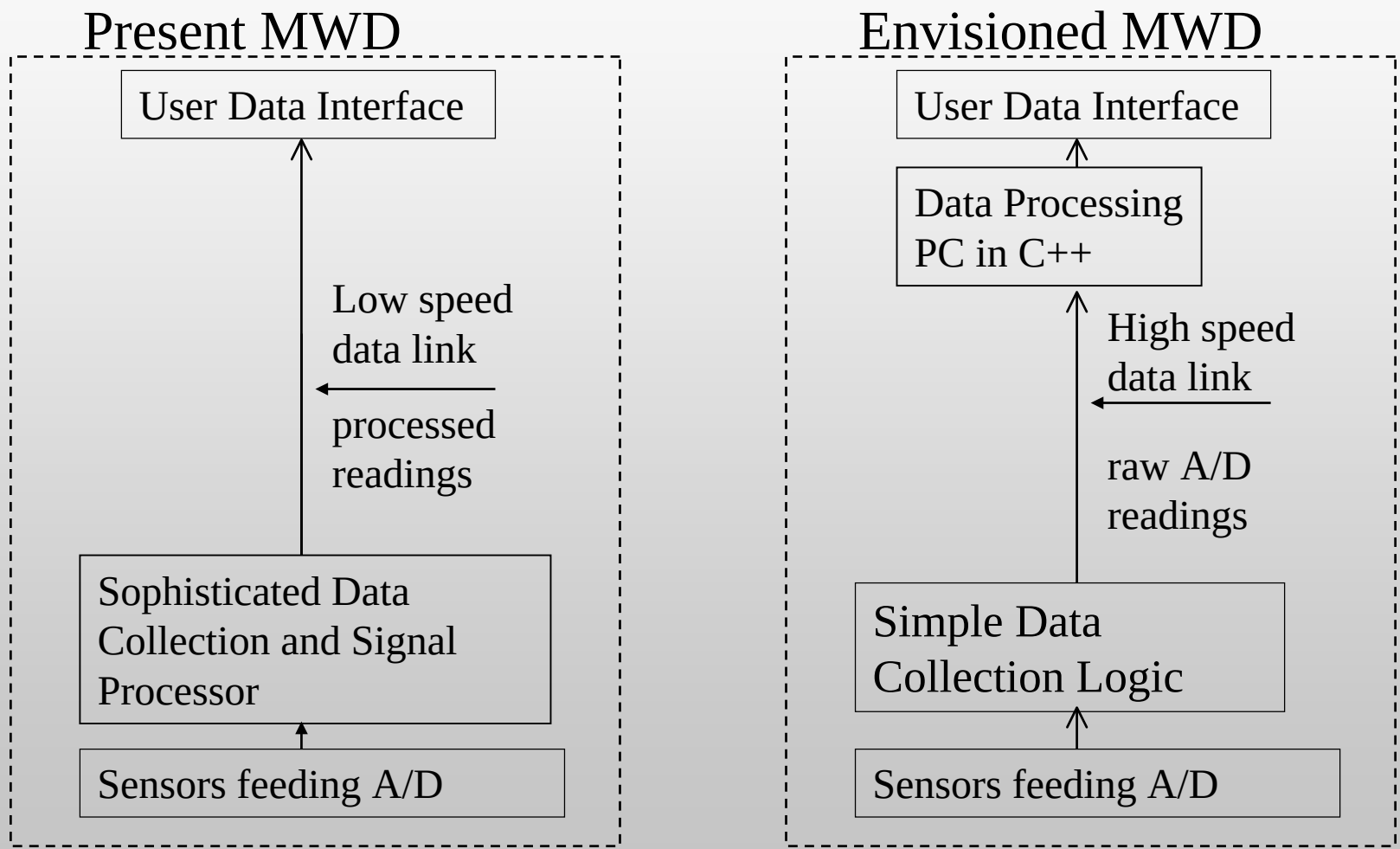
- Other components: solders and PC boards

New HT Battery

- **Rechargeable, Thin, Single Cell Battery**
  (Test Current = 60 ma)
  - We have batteries for 250°C and above
  - We have tested a 150°C-250°C battery prototype



Why HT Electronics and High-Speed Data Transmission is a Win-Win for MWD/DWD



The Last Word

- Sandia is focusing on component development needed for greatly improved downhole tools and systems
- We are on steep growth curve to establish a viable high-temperature and long life electronics industry to support a wide range of high-temperature applications
- Upgrading the HiTEC web site for more HT information: http://www.hitecconf.com/